Consequences of Federal Manure Management Proposals: Cost to Swine Operations from Land Applying Manure

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Abstract

A manure application cost model was used with survey data to examine the costs to confined

swine operations of meeting proposed mandatory nutrient management plans across regions and

size classes. Sector costs are examined under alternative scenarios involving nutrient standards,

and owner willingness to accept, and the use of phytase.

Key words: confined hogs, manure nutrients, nutrient management plan, phytase

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Land application is the predominant method for disposing animal manure and recycling its nutrient and organic content (USDA-EPA, 1999). Increased animal concentration and the accompanying reduction in land per animal unit has raised concerns that nutrients in waste are not being utilized by plants and are becoming increasingly likely to run off into water resources (USDA-EPA, 1999; Gollehon et al., 2001). Proper application rate is the single most important manure management practice affecting the potential contamination of water resources by manure nutrients (Mulla et al., 1999).

Policymakers are currently considering alternative mechanisms to ensure manure is applied to land in a way that increases the nutrient contributions of manure to crop yield, thus reducing damages from residual nutrients (Gollehon et al., 2001). The Unified Strategy for Animal Feeding Operations, jointly developed by USDA and EPA, states that "Land application is the most common, and usually most desirable method of utilizing manure because of the value of the nutrients and organic matter. Land application should be planned to ensure that the proper amounts of all nutrients are applied in a way that does not cause harm to the environment or to public health. Land application in accordance with the CNMP should minimize water quality and public health risk." (USDA-EPA, 1999, pp. 8-9). A goal of the Unified Strategy is that all animal feeding operations adopt CNMPs (comprehensive nutrient management plan) for managing their nutrient resources, both commercial fertilizer and animal manure.

Land application of waste at agronomic rates is also an important component of the rules proposed by EPA for changing the way animal operations are handled under the Clean Water Act. To fulfill part of the goals of the Unified Strategy and to mitigate the actual and potential

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water quality impacts posed by the largest animal feeding operations (CAFOs), EPA is revising the regulations for CAFOs (U.S. EPA, 2001). One of the proposed changes is to require CAFOs to develop and implement a nutrient management plan for applying animal wastes and commercial fertilizer to cropland. The plan would be nitrogen- or phosphorus-based, depending on phosphorus content of the soil, and would become part of the NPDES permit. The operations could only operate with a valid permit that is being properly followed. Violations of the permit would be subject to fines and/or facility closure.

Changes in nutrient standards for manure application will have an important bearing on manure application and hauling requirements. At the farm level, this could result in the need to find additional land on which to spread manure. Associated with this is the cost of transporting and applying animal waste to more land. Such costs may be substantial and dramatically affect the economic viability of the operation.

Hogs are a good example of the changes in the animal sector that have spurred the development of manure management proposals. In 1982 there were 175,284 farms with confined hogs that housed 6.3 million animals; by 1997 the number of farms with confined hogs had shrunk to 63,723, but they housed 8.2 million animals (USDA, ERS, 2002). An estimated 51 percent of nitrogen in confined hog manure that is available for land application is in excess of crop needs of the farm that produced the hogs (Gollehon et al., 2001). For phosphorus, the figure is 64 percent. Excess nutrients are believed to be prone to leaving the land where it is applied and to entering water resources. Proposed nutrient management planning for animal feeding operations would address these excess nutrients.

Evidence of Nutrient Over-application in the Hog Sector

We used data from the 1998 Agricultural Resource Management Study (ARMS) Hog survey to provide an example of how the proposed nutrient management goals of EPA and USDA might affect the hog sector (USDA, ERS, 2000b). The ARMS survey obtained more than 1,600 responses from 22 states. The survey target population was limited to farms with 25 or more hogs on the operation at any time. Each surveyed farm represents a number of similar farms in the population. The hog sample represents about 95 percent of the U.S. hog inventory in 1998. We grouped data into 5 multi-state regions: Eastern Cornbelt (IL, IN, MI, OH, WI); Western Cornbelt (IA, KS, MN, MO, NE, SD); Mid-Atlantic (NC, SC, VA); South (AL, AR, GA, KY, TN); West (CO, OK, UT). We looked at three size classes based on current EPA Clean Water regulations: small-sized operations (<300 animal units or AU), medium-sized operations (between 300 and 1000 AU) and large operations (>1000 AU). These are defined on the basis of EPA's definition of animal units, where one AU is 2.5 hogs weighing more than 55 pounds. Operations that contain only small hogs (reported on the survey as less than 60 lbs) are not included in the analysis, because EPA regulations do not currently affect them, and because there is no published definition of AU for pigs of this size. However, where an operation has a mixture of small and large hogs, the small hogs are included in the calculation of manure nutrients that the operation has to address.

The survey data indicated some differences between the regions and size classes. Hog densities (animals per unit of available cropland) were significantly different (at the 5 percent level) across regions, ranging from 2.5 AU/acre (or 6.26 animals/acre) in the Western Cornbelt to 32.4 AU/acre (81 animals/acre) in the Mid-Atlantic (table 1). Swine farms in the Cornbelt regions tend to be integrated with crop production to a higher degree than in other regions, and hence have a greater amount of cropland on the operation. Densities were also significantly

different across size classes, ranging from 1.4 AU/acre for small farms to 5.1 AU/acre for

medium farms and 17.2 AU/acre for large farms.

Regions also differ in the predominant waste handling technology. In the Eastern and

Western Cornbelt regions slurry systems are by far the most common (table 1). In the other three

regions, lagoon systems dominate. Slurry contains more nutrients per gallon of material than

lagoon liquid, but there is less volume of material that needs to be moved (Iowa State Extension,

1995).

The first question we want to address is whether farmers have enough assimilative

capacity in the crops they grow on their own farm to handle the manure nutrients they generate

over the course of a year. Data collected by the survey include number of hogs, hog types

(market hogs, feeder pigs), acreage and type of crop and pastureland on the farm, crop yields,

whether feed was treated with phytase, and whether manure was incorporated or surface applied.

We estimated the recoverable nutrients in the manure generated by each farm and the

assimilative capacity for the cropland controlled by the operation using the same procedures used

by Kellogg et al., (2000) and Gollehon et al., (2001) to evaluate Census of Agriculture data. The

two Census evaluations considered identified 24 crops suitable for receiving manure. We used

these same crops in identifying land suitable for receiving manure. For example, vegetables

were not included among available acres. Soybeans were not considered suitable for application

under a nitrogen-based nutrient management plan, but acceptable under a phosphorus-based

plan. Assimilative capacity was based on the amount of nutrients removed from the field with

the crop. Nutrients remaining in crop residue were assumed to be available for future crops.

There were significant differences in estimated potential nutrient removal by plants

across regions (at 5 percent level) (table 1). Average nitrogen removal ranged from 119.7

pounds/acre in the Western Cornbelt to 57 pounds/acre in the west. Phosphorus removal ranged from 76 pounds/acre in the Mid-Atlantic to 41.6 pounds/acre in the Eastern Cornbelt. These differences are due to the mix of crops grown on the farms and differences in yields for those crops across regions. Large standard deviations within each region indicate that there are wide variations across farms. When average nutrient removal is examined across farm size classes, there are no significant differences at the 5 percent level.

The nutrient content of manure can change dramatically from the time it is excreted to when it is actually applied to a field (Follett and Hatfield, 2001). Adjustments for nutrient losses in collection, storage, and transportation were based on the technologies reported in the survey and on loss coefficients reported in the literature (Iowa State Extension, 1995; Jones and Sutton, 2001; Sutton et al., 2001). To account for volatilization in the field, nitrogen values were reduced 5 percent if manure was incorporated, and 30 percent if it was surface applied.

We assumed that all hog manure was applied to land controlled by the operation. Data from the ARMS survey indicate that about one-fifth of all swine farms moved some of their manure off the farm to other users (table 2). Survey data did not allow us to estimate the percentage of manure moved off the farm, but we believe this to be small. Hog manure has a high moisture content and is costly to transport, so it is not likely to be voluntarily moved far from the confinement buildings.

If hog farms used all their suitable land for spreading manure, almost 84 percent of the small farms would have adequate acres to meet an N-based plan, and about 79 percent would have adequate acres to meet a P-based plan (table 3). In the West and Mid-Atlantic regions farms have notably less land that could be used for spreading than the other regions. As a result,

more than half the small farms in each of those regions would not meet the needs of a nutrient management plan, even if all land was used.

For large operations, about 31 percent could meet a N-based plan and 21 percent a P-based plan if all available land were fully utilized. Nearly 46 percent of large farms in the Eastern Cornbelt could meet an N-based plan if all suitable land were used. This drops to 7.8 percent in the Mid-Atlantic and 0 in the West. The Western Cornbelt had the highest percentage of large farms that could meet a P-based plan, at 32 percent. This drops to 2.6 percent in the Mid-Atlantic and 0 in the West.

Farm-level Manure Management Costs

The cost of applying nutrients at rates designed to meet crop needs has an important bearing on how the operation might adjust to meet a regulation's requirements. Assuming no other technologies for reducing the amount of manure to spread on the land or adjustments in herd size, the cost associated with restricting manure application to meet crop nutrient needs is the transportation and application cost for moving manure to more land than is currently being used. However, animal manure has value as a crop fertilizer. To the extent that animal manure can replace commercial fertilizer on cropland, there may be some cost savings from land application.

The survey data indicate that many farms, particularly large ones, will have to find large amounts of land off the farm for spreading manure. Even if land is available for spreading in the surrounding area (defined in this study as a county), not all landowners will be willing to take animal manure. There are several drawbacks to land application of manure that could discourage greater use on cropland. These include uncertainty associated with the nutrient availability, high

transportation and handling costs relative to commercial fertilizer, and public perception

regarding odor issues (Risse et al., 2001). The fewer landowners willing to use manure on their

cropland, the more costly it will be for livestock farms to move manure to enough suitable land.

Fleming, Babcock, and Wang (1998) developed a model for assessing the on-farm cost of

additional manure handling that environmental policies for controlling animal manure might

impose. The model has two components. One describes the handling and transportation costs

associated with spreading manure on cropland at agronomic rates. The other defines the net

fertilizer benefits of manure as a substitute for commercial fertilizer. Together, they estimate the

net cost to a farm for spreading manure at agronomic rates to meet the requirements of a nutrient

management plan, assuming a baseline of simple disposal (dumping) near the production facility.

We used the model to assess the costs for hog operations to transport and spread all their manure

at agronomic rates.

Costs

The Fleming model assumes that manure is delivered to surrounding crop fields by

custom manure applicators and spread at agronomic rates. The agronomic rate is defined here as

the rate of manure application that matches the uptake of nutrients in grain or plant matter that is

removed from the field. Modeling manure delivery costs requires information on three

components: (a) base charge (for manure mixing, loading, and application); (b) a mileage charge

(transporting the material to the field); and (c) the number of miles manure is hauled. For

manure slurry that is directly applied without being stored in lagoons, the mileage charge

represents time on the road in a vehicle from the production facility to the field and back. For

lagoon liquids that are sprayed on cropland, the mileage charge represents the cost of the added

equipment and assembly cost needed to deliver wastes to the field.

The cost equation is:

$$DC = QH \left[r_B + Z r_A \left(\left(\frac{N_M QH}{640 \alpha \beta \gamma N_C} \right)^{1/2} - 1 \right) \right].$$

Q = quantity of manure hauled per head (gallons)
H = number of head
r_A = unit mile charge (dollars per gallon per mile)
r_B = base charge (dollars per gallon)
Z = 2 for slurry systems (round trip for hauling vehicle), 1 for liquid waste (no return trip required)
N_C = nutrient need of crop for limiting nutrient (N or P, depending on which the plan is based on) (pounds per acre)
N_M = nutrient content of manure (pounds per gallon) for target nutrient (N or P)
α = proportion of surrounding land that is cropland
β = proportion of cropland that is suitable for receiving manure
γ = proportion of crop acres where manure is accepted by farmers.

The term $\dfrac{N_M QH}{N_C}$ is the required acreage (RA) for spreading the waste at agronomic rates.

Fleming et al. point out that suitable acreage is rarely available immediate to the site

where animals are produced, and that some amount of "searching" for suitable cropland will be

required. We assume that manure is only applied to cropland or pasture. Only a portion of

surrounding land will be cropland or pasture (α). The rest will be in other uses such as forest or

range. Only a portion of cropland will be suitable for spreading manure (β). For example, we

assume that vegetable crops do not receive manure. We also assume that soybeans and other

legumes do not receive manure under a nitrogen-based plan. Finally, only a portion of this land

will actually be available because of producer preference (γ). The equation $\dfrac{N_M QH}{\alpha \beta \gamma N_C}$ thus defines

the "searchable area".

Fleming et al. developed an algorithm for estimating the average distance traveled to spread manure in the searchable area. It is assumed that the searchable area is a square, contiguous block. Within this acreage is located one or more crop fields that are randomly selected for manure applications. Fields are assumed to be of the same size. Thus, a grid is formed where the outside edge defines the searchable area (SA), and the cells are the individual fields.

Given this grid, it is possible to calculate the distance from any point to any other point, sum these distances up, and divide by the number of points in the grid to calculate average distance. The shortest possible distance traveled will be 0. The greatest distance will be traveled when the entrance to a receptor field is on the perimeter of SA opposite the source. Maximum one-way mileage is two times the square root of SA divided by 640 (acres in a square mile).

As SA is divided into smaller and smaller fields, the distribution of mileage traveled approaches a normal curve. From statistics, the median point of a distribution will approach the mean as that distribution converges to the shape of a normal curve. Hence, the median distance, the sum of the minimum and maximum distance traveled divided by 2, is a good approximation of average distance traveled, and is easier to calculate (Fleming et al., 1998). Therefore, average distance traveled to spread manure over available cropland that accepts manure is

$\left(\dfrac{N_M Q H}{640 \alpha \beta \gamma N_C} \right)^{1/2}$. Generally the first mile is included in the base charge, so this distance is subtracted from average distance when the mileage cost is calculated (Fleming et al., 1998).

Benefits

Manure nutrients have value if they replace commercial fertilizer on cropland. The equation for calculating this benefit is:

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$$TB = QH \sum_{i=n,p,k} P_{M,i} N_{M,i} + aRA$$

$N_{M,i} AR_T \leq NC_i$, for T = n or p and i=n, p, k
$a = 0$ if $N_{M,i} AR_T < NC_i$ for i = n,p,k

$P_{M,i}$ = price of commercial fertilizer for nitrogen (n), phosphorus (p), and potassium (k)
$N_{M,i}$ = nutrient content of manure for n, p, and k
a = commercial fertilizer application cost (expressed in dollars/acre)
RA = required acreage for spreading
AR_T = application rate for manure (gallons per acre) based on the target nutrient T.

This equation says that nutrients in manure are valued at the price of commercial fertilizer only to the extent that plant needs are met. We assume that cropland not receiving manure is receiving commercial fertilizer at agronomic rates. If a nutrient is applied beyond plant needs, the over-application has a zero value. Also, the commercial fertilizer application cost is only a benefit if all the crops' nutrient needs are met by manure and commercial fertilizer is no longer applied. If one nutrient in manure is not sufficient to cover crop needs, then commercial fertilizer is applied to make up the deficit and the application cost must be paid.

When a hog farm can use all its manure on its own land, it directly benefits from the nutrient value of manure. To fully account for the benefits of manure, benefits are assumed to accrue to the hog farm even when manure is moved off the farm to other landowners. The analysis implicitly assumes that hog farms moving manure off the farm receive a payment equal to the nutrient value of manure.

The difference between costs from spreading manure on acceptable acres and the benefits of doing so are the net costs from spreading manure at agronomic rates. We used data from the 1998 ARMS hog survey to estimate the costs of land-applying manure for the Eastern Cornbelt, Western Cornbelt, Mid-Atlantic, South, and West regions. The farm-level data from ARMS enabled estimates to be made for each farm in the survey. The survey provided data on the

county in which the farm is located, number of animals (H), type of manure storage system (slurry pit or lagoon), whether manure was surface applied or incorporated, the total amount of cropland on the operation, the crops grown, and crop yields. Quantity of manure slurry or lagoon liquid hauled per head (Q), hauling and application charges (r_A and r_B), nutrient content of slurry or lagoon liquid (Nm), fertilizer prices (Pm), and fertilizer application cost (a) were obtained from published sources (Fleming et al., 1998; Jones et al., 2001; Iowa State Extension, 1995).

Crop nutrient uptakes (Nc) were found in Kellogg et al (2000). Appropriate crop nutrient uptakes were assigned based upon reported crop acreage and yield. Phosphorus uptakes were converted to phosphate to be compatible with manure nutrient concentrations. Those farms without cropland were assigned regional average nutrient uptakes based upon survey response.

Spreadable area for each operation was divided into two components. The first is the land available on the farm. We assumed that farmers would spread manure on their own land first, the amount of which was available from the survey. The willingness to accept (γ) for this land was assumed to be 1. Once their own land was fully utilized, farmers were assumed to spread on surrounding land in the county. Distance to suitable surrounding land was estimated with the Fleming model. We assumed that the percentage of surrounding land that was suitable for receiving manure was the same as for the entire county in which the farm was located. We used data from the 1997 National Resources Inventory to estimate the percentage of searchable area that is crop or pasture (α), and the percentage of crop or pastureland actually suitable for receiving manure (β). The percentage of landowners willing to take manure was initially assumed to be 10 percent ($\gamma = 0.1$), based on the ARMS crop survey data (USDA, ERS, 2000a).

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This factor was adjusted in alternative scenarios to ascertain the impact education might have on costs of manure management.

Results

The average amount of additional spreadable land needed by farms is shown in table 3 for N-based plans, P-based plans, and P-based plans assuming phytase is used by all farms. The costs of spreading on the basis of a nitrogen-based plan are lowest in the two Cornbelt regions, for all size classes and for all levels of landowner willingness-to-accept (figure 1). For large operations, costs are $16.90 per AU in the Eastern Cornbelt and $21.70 per AU in the Western Cornbelt when willingness to accept on the part of off-site landowners is 0.1. In contrast, costs in the Mid-Atlantic, South, and Western regions are $73.40, $65.40, and $72.60 per AU, respectively. The difference in costs is even more pronounced for small operations ($1.80 per AU in the Eastern Cornbelt vs. $48.40 in the West). There are three major reasons for this. First, hog operations in the Eastern and Western Cornbelt tend to be more integrated with grain production than in other regions, meaning that there is generally more land available per animal unit on the operation. For small farms, the two Cornbelt regions had the highest percentages of farms with enough land to meet an N-based plan (table 3). The average spreading costs for these farms are very low.

Second, grain production is a more pervasive land use in the Corn Belt regions than in the others. The availability of suitable cropland and pastureland for spreading off the farm (variable α in the model) is much higher in these regions than the others (78 percent vs. 20 percent in the Mid-Atlantic).

Third, nutrient uptake is generally higher in the Cornbelt regions because of the mix of crops grown and higher crop yields (table 1). Land can generally receive higher application rates, meaning that less land is needed off the farm per animal unit.

Large operations generally have higher average costs than smaller operations, across all regions. The higher costs for large operations reflect the higher ratio of animal units per acre of land. Only about 31 percent of large farms had enough land to meet an N-based plan, compared to nearly 84 percent for small farms. It is more costly to find land for spreading off the farm than to utilize land on the farm. Land on the farm is assumed to be closer to the confinement facility than land off the farm, to have a higher proportion of cropland than land off the farm, and to have a willingness to accept of 1. The greater the portion of manure that must be moved off the operation, the greater the average spreading cost.

Increasing the willingness of landowners who don't raise animals to use manure decreases the costs of meeting an N-based management plan by reducing the distance manure must be moved to reach "spreadable" fields. The reduction in costs is more significant for large operations, since they generally have to move a greater portion of their manure off the farm. One might conclude from this result that education or other programs that encourage landowners to use manure could greatly benefit confined animal operations and help reduce their costs of manure management. These results also indicate that animal operations may be willing to pay landowners an amount less than or equal to cost savings to utilize manure as a soil nutrient. For example, in the Mid-Atlantic, the average large operation might be willing to pay neighbors up to $17.80 per AU ($73.40-$55.60) to increase the overall willingness to accept from 0.1 to 0.2.

Requiring a phosphorus-based nutrient management plan generally increases the cost of manure management because more land is needed to meet the requirements of a phosphorus-

based plan, which increases the distance needed to find adequate land for spreading (figure 2). To the extent that farms grow soybeans, the amount of available acres will also increase under a P-based plan.

A similar regional pattern of costs emerges as for an N-based plan, with the two Cornbelt regions having much lower costs than the other regions. The West and Mid-Atlantic share the highest costs across all size classes.

An interesting result in the two Cornbelt regions is that meeting a phosphorus plan actually generates small, positive net returns for small farms. Net returns increase by $1.20 per AU in the Eastern Cornbelt and $0.50 per AU in the Western Cornbelt when willingness to accept is assumed to be 0.1. These are in contrast to the costs in the Mid-Atlantic, South, and West regions of $45.60, $25.90, and $49.70 per AU, respectively. The reason for this is that meeting a P-based plan more fully utilizes the full nutrient value of manure. Under a nitrogen-based plan, both phosphorus and potassium are over-applied. Nutrients in excess of crop needs have no economic value. Under a phosphorus-based plan, neither nitrogen nor phosphorus is in excess, so they are fully valued. Potassium may or may not be in excess, depending on the crop. The nutrient benefits under a P-based plan outweigh the additional costs of spreading on more land. Spreading costs are relatively low in the Cornbelt regions because small farms tend to have enough of their own land to meet the requirements of the plan, and it is easier to find spreadable land off the farm than in other regions. For all other size classes in the Eastern and Western Cornbelt, and generally in all other regions, costs per AU increase under a P-based plan because the costs of moving manure off the farm to more acres outweigh the increased nutrient value of manure.

One of the management options for reducing the phosphorus content of manure is to supplement the feed with the phytase. Phytase is an enzyme that enables non-ruminants to better utilize phosphorus in grain, thus reducing the need to add the mineral di-phosphate to feed. The addition of the phytase to hog feed can reduce the phosphorus content of waste by up to 45 percent (Harper, 2000). The survey results indicate that phytase was not widely used (table 2). It is used most often by large operations, but less than 16 percent used it in 1998. Less than 4 percent of small operations used phytase-treated feed. We assumed that phytase reduced phosphorus content of animal waste by 30 percent.

Reducing the phosphorus content reduces the amount of land that is needed for spreading (table 3). If all operations use phytase, the land application costs for most operations are reduced (figure 3). The benefits are greatest for the large operations. For example, the cost for a large operation in the Mid-Atlantic facing a willingness to accept of 0.1 declined from about $95.90 to $82.30 per AU. Small operations benefit the least. For small operations in the Cornbelt regions, manure handling costs actually increase because the manure has less value as a fertilizer. The benefits from phytase are greatest for large operations, and decrease as willingness to accept manure increases.

Conclusions

The results of this analysis lead to some general conclusions about land application of animal waste.

- Land application costs increase on a per-unit basis with the size of the operation. This is due primarily to an increase in the number of animals per-acre of owned cropland, and the

costs of finding and transporting manure to adequate land off the farm to handle a greater amount of manure nutrients.

- Regions with a higher density of cropland have lower costs (primarily the Midwest). Assuming similar willingness to accept, transportation costs are lower.
- Increasing non-livestock crop producers' willingness to accept manure lowers the overall nutrient management costs for confined animal operations. The figures show generally decreasing cost from increased willingness to accept.

New manure management requirements would require a high percentage of large hog operations to seek additional land for spreading, at potentially significant costs. Most small operations have adequate land to handle their own manure, so land application costs to them would be much lower. A caveat to these results is that they do not reflect changes in management other than spreading waste on additional acres. Evaluating this issue using an optimization framework where all aspects of the operation could be adjusted would shed additional light on the management changes and associated costs needed to meet a nutrient management plan. Options farmers might take include growing crops that take up more nutrients, changing waste handling so that nitrogen is lost to the atmosphere, and reducing herd size. These changes would occur over time, and at some expense. The results reported here can be viewed as an initial adjustment to the policy that might then lead to further changes as the farmer evaluated the costs of spreading and considered alternative or additional changes.

Table 1 - Summary of manure storage, hog density, and nutrient uptake, by region.

Region	Percentage of farms using lagoons*	Animal units per acre owned[1]	Average nitrogen uptake (lbs/acre)[1]	Average phosphorus uptake (lbs/acre)[1]
Eastern Cornbelt	18.2	3.7	106.3	41.6
Western Cornbelt	24.5	2.5	119.7	75.6
Mid-Atlantic	97.7	32.4	103.5	76.0
South	79.8	5.8	82.2	42.5
West	89.1	7.6	57.0	55.3

*remainder are slurry systems.

[1]The hypothesis that mean values are the same across all regions was rejected at the 5 percent level using an F-test.

Table 2 - Phytase use and manure removal by hog farms, by region
and size, 1998.

Region	Number of farms	Use phytase in feed	Move some manure off the farm
Eastern Cornbelt	number	percent	
<300 AU	5,891	5.4	13.2
300-1000 AU	2,658	20.0	29.5
>1000 AU	1,110	21.9	26.5
Western Cornbelt			
<300 AU	10,903	2.5	20.4
300-1000 AU	7,744	4.9	22.8
>1000 AU	2,025	15.6	34.2
Mid-Atlantic			
<300 AU	423	0.6	1.9
300-1000 AU	582	14.2	6.4
>1000 AU	1,214	11.6	1.8
South			
<300 AU	1,236	3.2	21.0
300-1000 AU	488	13.9	12.5
>1000 AU	177	17.8	16.4
West			
<300 AU	393	3.1	44.0
300-1000 AU	108	47.4	47.4
>1000 AU	174	0	0
Nation			
<300 AU	18,846	3.5	18.3
300-1000 AU	11,580	9.7	23.3
>1000 AU	4,700	15.6	22.1

Source: 1998 ARMS hog survey.

Eastern Cornbelt includes IL, IN, MI, OH, WI
Western Cornbelt includes IA, KS, MN, MO, NE, SD
Mid-Atlantic includes NC, SC, VA
South includes AL, AR, GA, KY, TN
West includes CO, OK, UT

Table 3 - Percentage of hog farms meeting N-based and P-based plans and additional land needs, by region and size, 1998.

Region	Farms with adequate land for N-based plan	Farms with adequate land for P-based plan	Additional land to meet N-based plan	Additional land to meet P-based plan	Additional land to meet P-based plan, all phytase
Eastern Cornbelt	percent		acres		
<300 AU	80.2	73.1	53.8	130.1	93.1
300 - 1000 AU	64.4	59.9	181.9	409.7	311.4
>1000 AU	45.7	25.5	490.1	1,141.6	858.8
Western Cornbelt					
<300 AU	88.6	85.5	48.7	136.6	96.3
300 - 1000 AU	66.8	53.8	170.6	406.7	289.7
>1000 AU	38.4	32.5	505.0	1,174.8	849.8
Mid-Atlantic					
<300 AU	46.6	49.4	42.2	107.7	75.8
300 - 1000 AU	16.8	7.8	226.9	361.1	262.8
>1000 AU	7.8	2.6	605.0	1,279.6	933.6
South					
<300 AU	81.6	69.2	37.7	75.6	53.7
300 - 1000 AU	55.5	55.2	137.4	297.6	216.4
>1000 AU	32.0	16.6	726.5	728.8	593.1
West					
<300 AU	42.5	37.6	120.8	132.2	93.0
300 - 1000 AU	0	0	189.0	294.2	234.2
>1000 AU	0	0	1,025.1	2,102.7	1,471.9
Nation					
<300 AU	83.6	78.7	50.9	129.8	92.0
300 - 1000 AU	62.5	52.4	174.8	399.4	289.7
>1000 AU	30.6	21.3	554.9	1,211.6	886.9

Source: 1998 ARMS hog survey.

Eastern Cornbelt includes IL, IN, MI, OH, WI
Western Cornbelt includes IA, KS, MN, MO, NE, SD
Mid-Atlantic includes NC, SC, VA
South includes AL, AR, GA, KY, TN
West includes CO, OK, UT

Figure 1 - Net cost of applying manure following a nitrogen-based plan, by region.
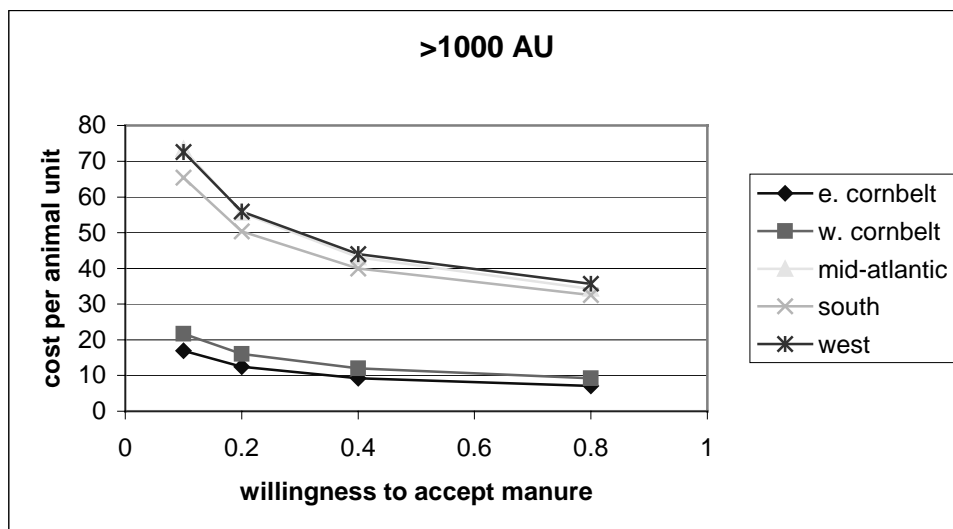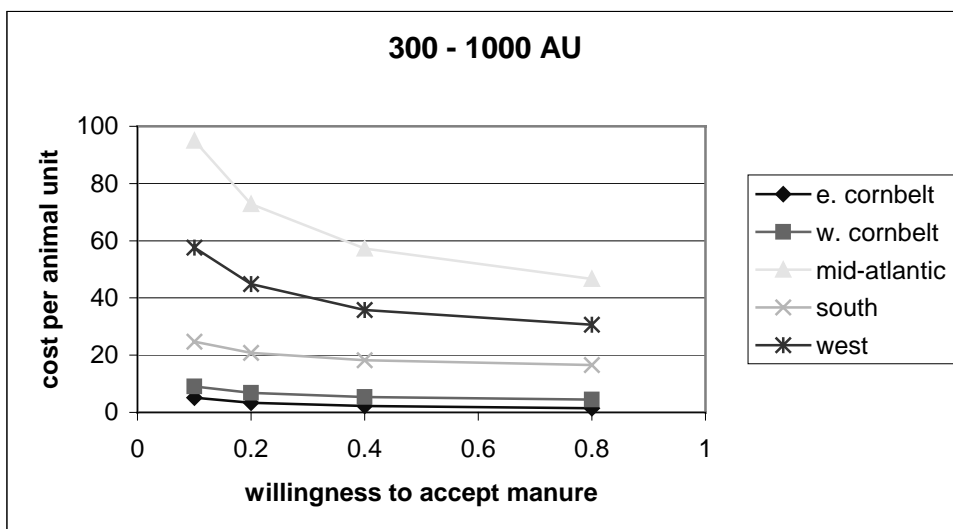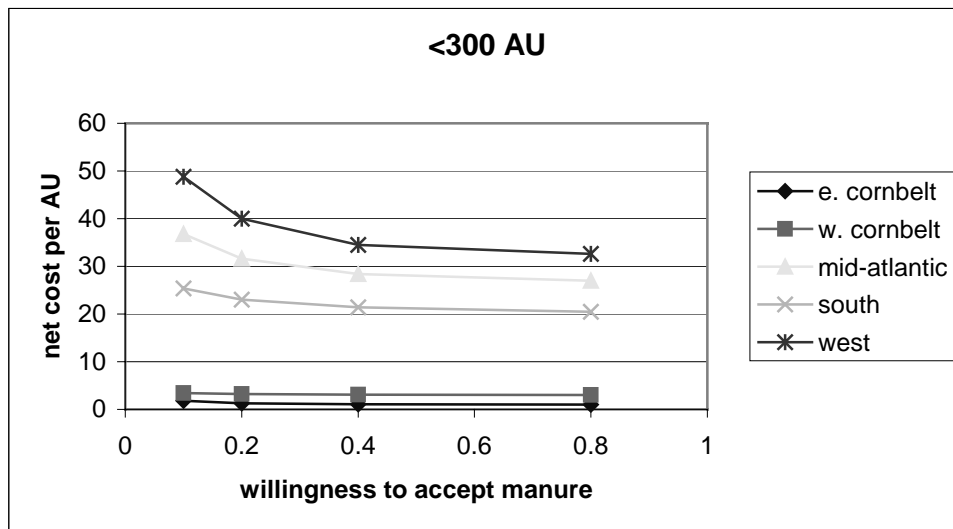
The graph for the Mid-Atlantic is almost co-incident with that of the West.

Figure 2 - Net cost of spreading manure following a phosphorus plan, current phtyase use, by region.

<300 AU

net cost per AU vs willingness to accept manure

Legend: e. cornbelt, w. cornbelt, mid-atlantic, south, west

300 - 1000 AU

cost per animal unit vs willingness to accept manure

Legend: e. cornbelt, w. cornbelt, mid-atlantic, south, west

>1000 AU

cost per animal unit vs willingness to accept manure

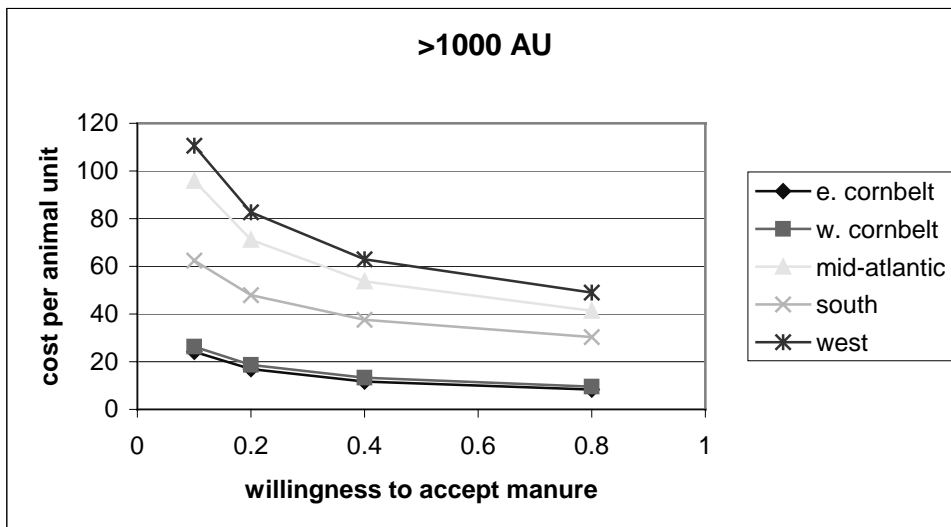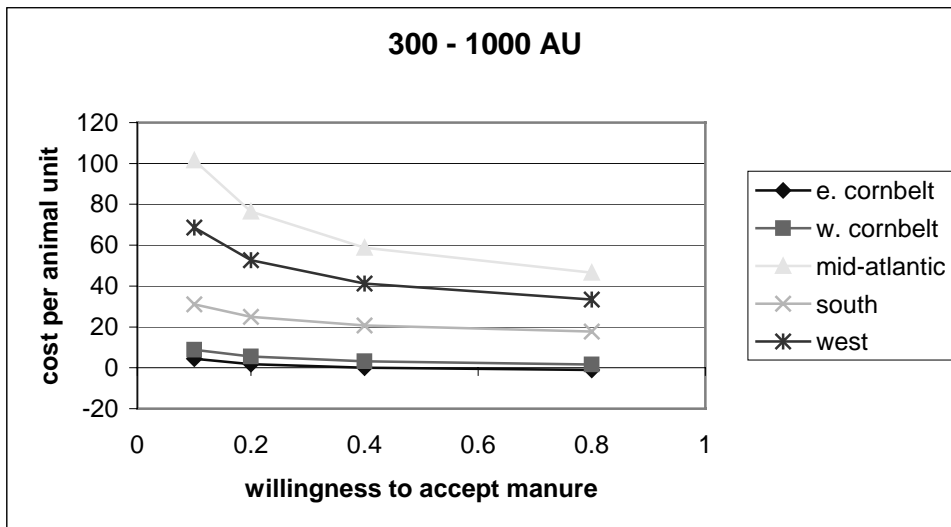Legend: e. cornbelt, w. cornbelt, mid-atlantic, south, west
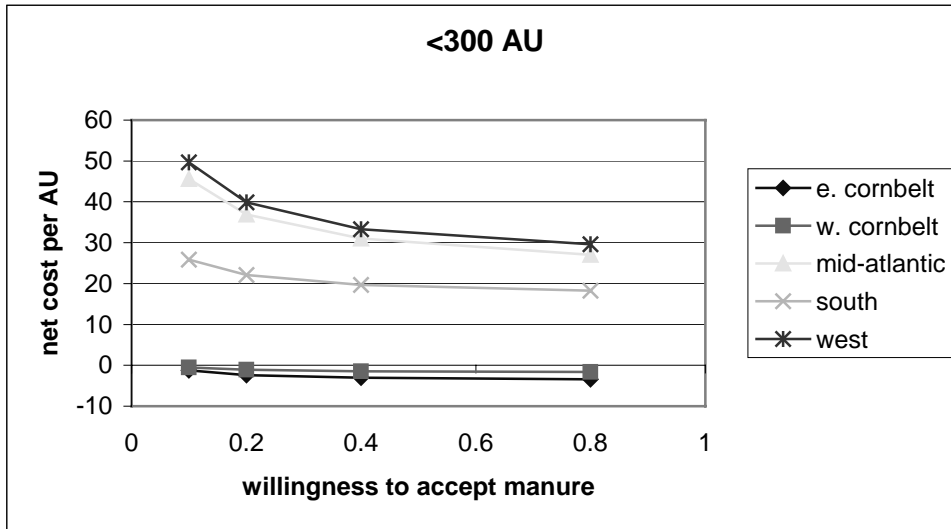
Figure 3 - Net cost of spreading manure following a phosphorus-based plan with all

<300 AU

net cost per AU / willingness to accept manure

- e. cornbelt
- w. cornbelt
- mid-atlantic
- south
- west

300 - 1000 AU

cost per animal unit / willingness to accept manure

- e. cornbelt
- w. cornbelt
- mid-atlantic
- south
- west

>1000 AU

cost per animal unit / willingness to accept manure

- e. cornbelt
- w. cornbelt
- mid-atlantic
- south
- west
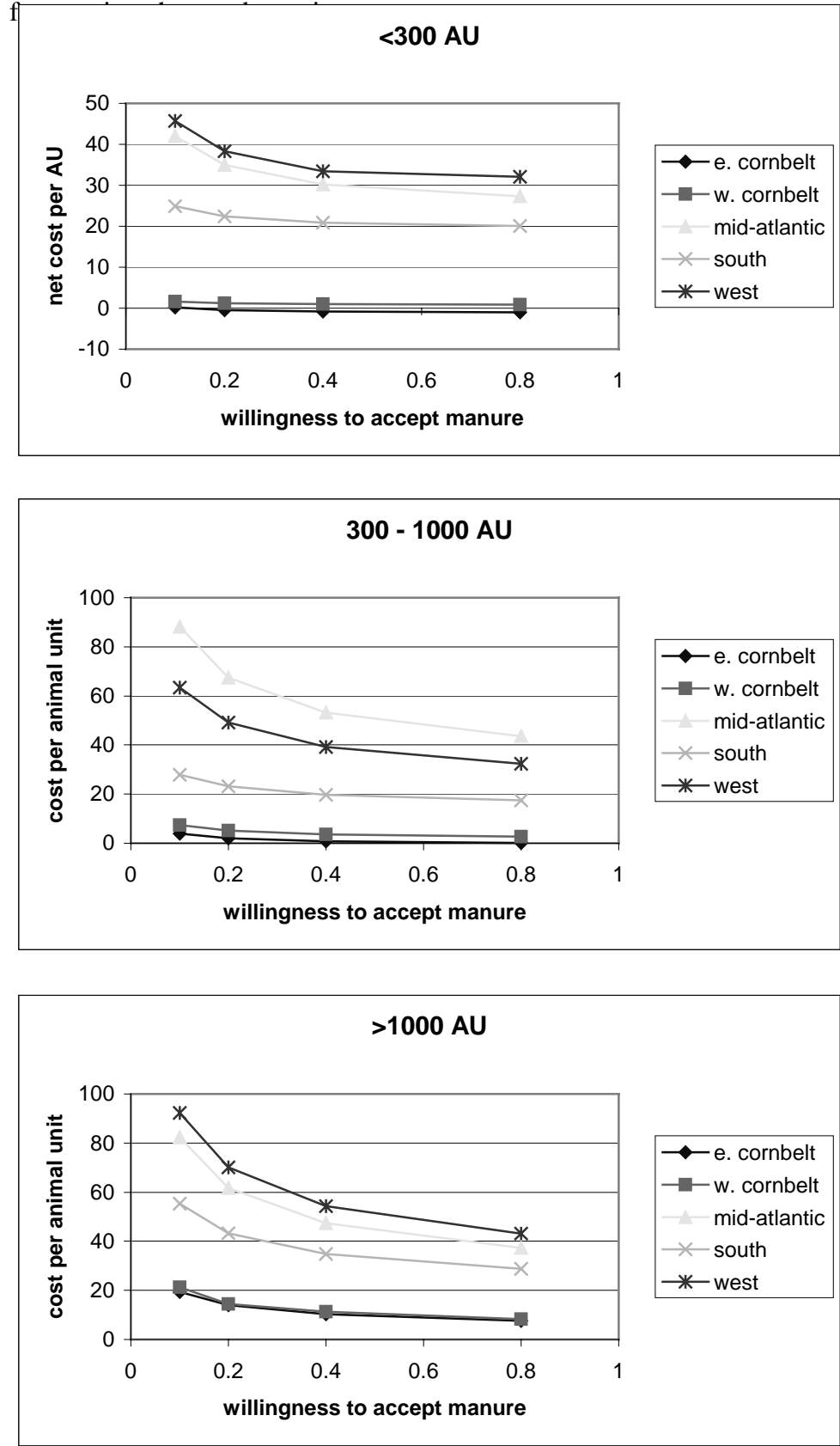
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